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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01M 8/02, 8/24, C25B 9/00	A1	(11) International Publication Number: WO 99/67845 (43) International Publication Date: 29 December 1999 (29.12.99)

(21) International Application Number: PCT/CA99/00583

(22) International Filing Date: 21 June 1999 (21.06.99)

(30) Priority Data:
2,241,566 23 June 1998 (23.06.98) CA

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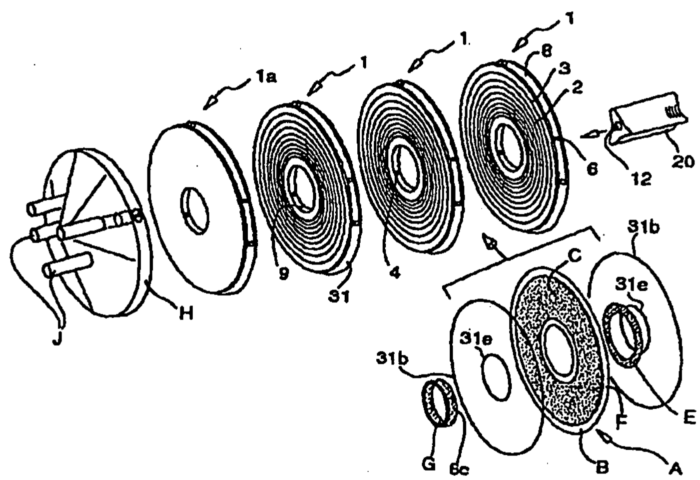
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: FLOW FIELD PLATE



(57) Abstract

A flow field plate (1) has surface layers of electrically conductive material, and a core layer of electrically conductive material between the surface layers within the thickness of the plate; the plate defines multiple sets of fluid passages comprising first sets of passages (2, 3, 10), one set formed in the thickness of each surface layer and open to and parallel to the surface of that layer, a second set (4, 5, 6) of passages formed in the thickness of the core layer and extending transversely to the passages of the first sets to provide points of intersection with the latter when viewed in plan, ports (4a, 5a, 6a) placing passages of the second set in communication with passages of one or other of the first sets at points of intersection of the passages, and a third set of passages (4d, 5d, 6d) extending perpendicularly through the layers, without intersecting the first sets of passages, and each communicating with a passage or passages of the second set to provide fluid paths into, out of, or through the first sets of passages via the second set of passages.

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FLOW FIELD PLATE

This invention relates to flow field plates. Flow field plates are typically used in fuel cell stacks in which they perform several functions.

In a typical fuel cell stack of the membrane type as described for example in U.S. Patent No. 3,134,696, membranes are sandwiched between porous catalytic electrode layers, and in turn between flow field plates which separate the cells in the stack. The flow field plates perform multiple functions. They act as current collectors for the electrodes and they provide electrical continuity between adjacent cells. They separately distribute reagent gases (oxygen and hydrogen) across opposite faces of the plate in connect with opposite polarity electrodes of adjacent cells. They remove the product of reaction (water) typically from the oxygen side, and should supply adequate moisture to the hydrogen side to prevent dehydration of the membrane. They act to conduct away heat generated at the membrane during operation of the cell. These multiple functions result in such plates having a complex structure and being expensive to produce. Flow field plate construction of diverse types are exemplified by U.S. Patents Nos. 3,814,631 (Warszawski et al); 4,125,676 (Maricle et al); 4,615,955 (Amakawa et al); 4,649,091 (McElroy); 4,937,152 (Sato et al); 5,108,849 (Watkins et al); 5,300,370 (Washington et al); 5,445,904 (Kaufman); 5,484,666 (Gibb et al); 5,514,487 (Washington et al); 5,683,828 (Spear et al); 5,707,755 (Grot) and 5,709,961 (Cisar et al).

It is an object of the invention to provide a flow field plate which is effective to carry out its function, but relatively simple and economical to manufacture.

According to the invention in a first aspect, there is provided a flow field plate comprising surface layers of electrically conductive material, a core layer of electrically conductive material between the surface layers

within the thickness of the plate, wherein the plate defines multiple sets of fluid passages comprising first sets of passages, one set formed in the thickness of each surface layer and open to and parallel to the surface of that layer, a second set of passages formed in the thickness of the core layer and extending transversely to the passages of the first sets to provide points of intersection with the latter when viewed in plan, ports placing passages of the second set in communication with passages of one or other of the first sets of points of intersection of the passages, and a third set of passages extending perpendicularly through the layers, without intersection passages of the first sets, and each communicating with a passage or passages of the second set to provide fluid paths into, out of, or through the first sets of passages via the second set of passages. The surface or core layers may be formed integrally or as a sandwich construction. The first sets of passages are preferably machined into the surface layer in a concentric circular or helical pattern. The layers may be formed of graphite or formed or metallized with a metal or other conductive material resistant to corrosion under the operating conditions of a fuel cell.

In U.S. patent No. 4,615,955 (Amakawa et al), an arrangement is shown in which the oxygen electrodes of a fuel cell or adjacent flow field plates have separate sets of passages, which may be interdigitated, for supplying oxygen or air and removing water and surplus gas such as nitrogen and unused oxygen. Both sets of passages are single ended, such that the air and the products of reaction pass unidirectionally through the electrode material between the sets. While this has the advantage of that the air and products of reaction move through the electrode material in cocurrent, it also requires that all of the air supplied passes through the electrode material. In one preferred arrangement in accordance with the invention, a through flow of reagents is

provided in the grooves on both sides of the plates, the hydrogen grooves being provided with both entry and exit passages, and the air/oxygen passages having some communication with or being common with water passages. This both enables enhanced cooling of the cells to be achieved by the passage of extra fluids, and enhances the removal of products of reaction, thus preventing water logging of the cells. The addition of wicking functions in the grooves and passages enhances the water handling capabilities of the cell.

The invention also extends to cell configurations which reduce or eliminate the necessity for large diameter O-rings, which are expensive and difficult to manipulate during assembly.

Further features of the invention will be apparent from the appended claims and from the following description of presently preferred embodiments of the invention with reference to the accompanying drawings, in which:

Figure 1 is an exploded view of a fuel cell stack incorporating a first embodiment of flow field plate;

Figure 2 is a plan view of the flow field plate shown in Figure 1;

Figure 3 is a plan view of a modification of the flow field plate shown in Figure 2;

Figure 4 is a fragmentary cross-section on the line 4-4 in Figure 3;

Figures 5-7 are plan views from the same side of separately formed layers of a second embodiment of flow field plate;

Figure 8 is an exploded isometric view of the embodiment of Figures 5-7;

Figure 9 is a plan view of a third embodiment of flow field plate;

Figure 10 is a cross-section of a variation of the embodiment of Figure 9;

Figure 11 is a plan view of a fourth embodiment of flow field plate;

Figure 12 is a cross section through a stack structure somewhat similar to that of Figure 3, but incorporating modifications;

Figure 13 and 14 are fragmentary cross-sections through portions of a fuel cell illustrating methods of installing seals;

Figure 15 is a section through a seal formed by the method illustrated in Figure 14;

Figure 16 is a radial section, through a core portion of a fuel cell stack;

Figure 17 is a perspective fragmentary view illustrating the use of wicks in flow field plate grooves;

Figure 18 is a plan view of an exemplary flow field plate groove arrangement;

Figures 19 and 20 are diametrical sectional and plan views of a core element for use in a fuel cell stack;

Figure 21 is an axial section through such a stack with only

two cells shown; and Figure 22 is an enlarged detail of Figure 21.

Referring first to Figure 1, there is shown in exploded view components of a fuel cell stack incorporating flow field plates 1 in accordance with the invention; end flow field plates 1a in the stack may, as shown, be single rather than double sided since the face adjacent an end cap will not form part of a cell. The cells in the stack are formed by electrode assemblies, of which only one is shown, inserted between adjacent flow field plates. Each electrode assembly comprises, in this example, a proton exchange membrane B, on each side of which are located porous graphitic electrode layers C & F. It should be understood that flow field plates in accordance with the invention could also be utilized with other types of electrode assembly presenting planar electrode surfaces to the plates, and in other types of electrochemical cell stacks, for example cells using electrical power to disassociate electrolytes into gases rather than the reverse process that takes place in fuel cells, although fuel cells are presently seen as a primary electrochemical application for the plates.

The membrane B is clamped adjacent its outer periphery and adjacent a central aperture by 0-rings 31b and 31e located in grooves 31d (see Figure 4) in the adjacent flow field plates when the stack of flow field plates and electrode assemblies is clamped between end plates (of which only one is shown) by an axial tie rod (not shown) passing through a central bore 12 in a core member 20 on which the electrode assemblies and flow field plates are assembled. Elastomeric collars G within the central bores 9 of the flow field plates interact with the apices of core 20 to define three channels 4d, 5d and 6d extending through the bores 12 longitudinally of the stack forming fluid passages for oxygen, hydrogen and water, these passages communicating with ports J in the end cap H.

Washers E may optionally or alternatively be used to seal the passages so formed at the membranes B.

Opposite surface layers of the plates 1 are formed with a series of concentric grooves forming first sets of channels covering an annular area between the O-rings 31b and 31e, this area corresponding to that of the electrodes C and F. In the sides of the plates seen in Figures 1 and 2, the set of grooves comprises alternating grooves 2 and 3, while on the opposite side (see Figure 4) there is one set of grooves 10. Although the grooves shown are circular, single or multistart helices could be utilised, or other easily machined layouts. If the grooves are moulded, a wider range of layouts is available. It may be advantageous to offset radially the positions of grooves on opposite sides of the plate so that the grooves on adjacent plates interdigitate. This improves the contact of the plates with the membranes when the stack is compressed, thus reducing electrical and thermal contact resistance.

Radial bores 4, 5 and 6, forming a second set of channels, extend through core layers of the plates 1 between the surface layers, and communicate respectively with the grooves 2, 3 and 10 through ports or vias 4a, 5a and 6a respectively. The bores 4, 5 and 6 communicate with the channels 4d, 5d and 6d, forming a third set of channels through ports of which only port 6c is referenced. The channels 4d, 4 and 2 of each plate conduct oxygen to fields adjacent the electrodes F adjoining electrode assemblies on one side of the plate, and the channels 6d, 6 and 10 of each plate conduct hydrogen to fields adjacent the electrodes of the electrode assemblies adjoining the other sides of the plates. The channels 3, 5a and 5d conduct water, formed by reaction between the oxygen and the hydrogen of the membrane under the influence of the catalyst treated electrodes, as well as excess oxygen, away from the reaction zone. The width and shape of lands 3a

between the grooves 2 and 3 may be controlled (compare Figure 10) so as to maximize the area of the electrodes exposed to the reagent fields, and having regard to the porosity of the electrode material to allow oxygen and water to migrate from the channels 2 towards the channels 3. The width and shape of lands between the channels 10 may be similarly controlled. Since the channels nearest the centre of the plate are shorter, it may be desirable to make these channels narrower or shallower so as to reduce the fluid flow through these channels compared to those of greater radius.

The channels 4, 5 and 6 may be formed by drillings closed at their outer ends by a further O-ring 31 retained in a channel 8 around the periphery of each plate 1.

The reaction between the hydrogen and the oxygen at the membrane is exothermic, and for maximum performance it is desirable to provide additional cooling of the assembly during operation. This is facilitated by the modification of the plate shown in Figure 2 as illustrated in Figure 3. As compared with the plate of Figure 2, the core member 20, instead of being approximately triangular, is in the form of a five pointed star so as to define five rather than three passages within the bores 9. The additional radial passages 11 and 11a communicate with additional radial bores 11c and 11d in the plate, while the O-ring 31 is replaced by a sealing collar 31c so as to enclose the channel 8 around the periphery of the plate. The channels 4, 5 and 6 are closed at their outer ends by plugs 4c, 5c and 6c. Cooling liquid may be fed to the stack through the channel 11 and exit through the channel 11a after passing through the plates via the channels 11c, 11d and 8. In a variation of this arrangement, the bores 11c and 11d are used to house heat pipes (not shown) rather than to act as water channels, with outer ends of the heat pipes being cooled to extract heat from the interior of the plates.

The plates 1 may be constructed in various ways. In one presently preferred form, a disc of graphite is machined on its opposite faces to form the grooves 2, 3 and 10 and on its periphery to form the channel 8. Such circular grooves are readily machined even in a material such as graphite. The radial bores are drilled. Rather than graphite, the plate may be formed of metal such as a noble metal or corrosion resistant alloy, but noble metals are very costly, and corrosion resistance, or, in the case of metals such as titanium or tantalum, may be costly and difficult to machine. Various chemically conductive resins are known and may be used; highly conductive resins containing up to 90% of graphite are available.

Another possible approach is to mould or cast the plate with at least the surface grooves, drill the radial passages, and metallize the completed plate using a noble metal. In this case the plate may be machined, cast or moulded from base metal or synthetic resin, provided that the integrity of the metallization of the various passages can be assured if the substrate material is not itself corrosion resistant. In the drawings the ports or vias 4a, 5a and 6a are shown as separately formed, but it may be practical to displace the radial drillings sufficiently towards the relevant surfaces of the plate that the primary and secondary passages intersect without additional drillings. If the plates are used in a non-electrochemical application, then their conductivity may be immaterial, and they can be moulded or machined from synthetic resin.

In use in a fuel cell, the stack incorporating the plates is preferably operated with the passages 2 and 3 facing upwardly, so that water formed by interaction at the membrane of oxygen and hydrogen accumulates in and is drained from the passages 3.

Turning now to Figures 5 to 8, an alternative embodiment of plate is shown, in which the same reference numerals are utilized to indicate similar parts. The opportunity has been taken in the several Figures to illustrate variations of this embodiment, but collectively the Figures show respectively a first surface layer 100, a core layer 101 and a second surface layer 102 which are assembled in the relationship shown in Figure 8 to form a complete plate. Each layer may for example be formed by either as already described above, or by embossing a sheet of a deformable graphitic composition to form the various passages. For example, the grooves 2, 3 and 10 may be pressed into the outer layers, and the secondary passages pressed into the appropriate side of the centre layer 10. Such pressed passages, such as the passage 50, in the centre layer will weaken it less than punched or drilled slots such as 6 or 40. The passage may communicate with a central passage 9, divided by a core 20, through ports 40d, 50d, or with off-centre through passages such as 13. As seen in Figure 6, the arrangement may incorporate cooling passages, as described above with reference to Figure 3.

Rather than endeavour to form multiple slots or grooves in a single layer of material, the core layer 101 may comprise multiple overlaid discs, each one of which is recessed or slotted to form only certain passages. For example, the layer 101 as shown in Figure 8 could be formed as two layers, one containing the vertical passages, and one the horizontal passages, or different sets of passages can be formed on opposite sides of the core layer, which may be formed of metal rather than graphite. This simplifies the structure of the outer graphite layers, in turn relaxing the specification required for the graphite.

Referring now to Figures 9 and 10, these Figures illustrate an embodiment incorporating certain variations of the embodiments of Figures 1-4. For example, the drilled

passages in the core layer of the plate need not be radial, so long as they can intersect the passages 2, 3 and 10. Moreover, the third passages extending longitudinally of the stack need not be located in the centre portions of the plates. In Figure 8, a non-radial passage 90 extends between longitudinal passages 70,80, sealed to passages of adjacent plates by O-rings 31b. The passages 70,80 are radially outward of the O-rings 31b. In Figures 9 and 10 a group of longitudinal passages 13 sealed by O-rings 13a provide for admission of hydrogen, oxygen and cooling water, while a central passage 12 provides for drainage of water produced by reaction, and for the passage of a tie rod (not shown).

Figure 11 shows how multiple stacks of cells may be assembled using a single set of plates 1. The plates in this case are rectangular, the stack being held together by the rods (not shown) through passages 12. The drillings 4, 5 and 6 (closed at the edge of the plate by plugs such as 6c) may be connected to longitudinal passages formed either by the passages 12, or segments of a central (relative to the grooves 2, 3) core 20, as previously described.

Although the passages 1, 2 and 3 have been described as circular and concentric, helical grooves could be employed to form the the passages and are easily machined. Separation of the passages 2 and 3 can be achieved in this case by use of a multi-start helix. In cases where the grooves must be machined from a material such as graphite, complex groove layouts should be avoided.

Figure 12 is a fragmentary section through a cell stack generally similar to Figure 2, with additional features discussed further below. O-ring seals are replaced by C-section seals 110 and 111, whose C-sections embrace inner and outer peripheries of the graphitic layers C and F sandwiching the membrane B. The seals 110 and 111 are located in

circular grooves formed in the plates 1. This both reduces the number of seals required, and eases their handling since they may be preapplied to the membrane assemblies. If the membrane assemblies have substantially the same diameter as the flow field plates 1, then the grooves may be replaced by rabbets (see Figure 13) at the inner and/or outer peripheries of the plates, permitting the seals to be applied during assembly of the stack, possibly with the use of a sealant between the seals and the stack, and/or peripheral retaining rings to hold the seals in place.

In a development of this arrangement, the C-section seals are formed <u>in situ</u>, as described in more detail with reference to Figures 13 through 16. In each case (see Figure 13) external grooves formed by the rabbets 112 on the plates are filled with an elastomeric resin, for example a silicone resin, which is cured in situ. One method of filling the internal grooves, and simultaneously forming the sleeve 9 (see Figures 2 and 3) is shown in Figures 14 and 15. Removable plugs 120 are inserted in all inwardly opening radial passages in the plates, and a further cylindrical plug 122 is inserted within a central bore in the plate stack, leaving a cavity to receive liquid resin injected through a dedicated radial passage 124, and cured in situ so as to form the seals 111 and the sleeve 9 as an integral unit (see Figure 15).

A second method is illustrated in Figure 16. A core member 20 within sleeve 9 defines multiple longitudinal passages 4D, 5D, 6D, 11, 11A and 130 within a centre core of a fuel cell stack, most of which passages communicate with radial passages in flow field plates 1 through ports in the sleeve 9, as described in more detail with reference to Figure 3. At least one passage 130 however communicates through ports 132 of the sleeve 9 with grooves formed by the rabbets 112 around the peripheries of the electrode assemblies, and is used to inject resin into these grooves. The passage 130 may

advantageously be located between the passages 4D and 6D carrying oxygen (air) and hydrogen respectively so as to improve the sealing between these passages.

Two particular problems encountered in the operation of fuel cell stacks are achieving adequate cooling of the cells so as to dissipate heat of reaction associated with the operation of the cells, and removing of water of reaction to avoid waterlogging of the cell on the oxygen side while preventing drying out on the hydrogen side. It will be noted that in Figure 12, the passages formed in the opposite surfaces of the plates 1 contain wicks 40. These wicks provide communication with bodies of water. In the case of the oxygen channels, the wicks withdraw water of reaction from the vicinity of the electrodes, while in the case of the hydrogen channels, they feed moisture to the channels. In each case, the flow of gas through the channels lends tends to evaporate water from the extended evaporative surfaces provided by the wicks, the heat of evaporation of the water providing a useful additional cooling effect. It is preferred that the channels or grooves on the oxygen side are arranged as shown in Figures 2 and 3, with alternate oxygen (air grooves 4 through which air or oxygen is circulated, and water grooves 5 through which excess water is withdrawn). Operation is shown in more detail in Figures 17 and 18. Oxygen or air possibly together with water is supplied through the passages 4 to alternate channels 2. Water is absorbed by the wicks 40 from the electrode F as it is formed or permeates from the latter, and at the same time is evaporated from the wicks to provide a cooling effect to the extent permitted by saturation of the gas passing through the system. Water may similarly be evaporated from wicks on the hydrogen side of the membrane, both to humidify the hydrogen electrode B, and to produce further cooling occasioned by the evaporative process. As best seen in Figure 18, oxygen or air passes into the channels 2 through ports 4A from the passages 4,

around these channels, through ports 44 to adjacent water draining passages 3 and exits through ports 5A to the passages 5. This arrangement permits additional air to pass through the system to the extent that it can pass between the passages 3 and 2, and across the lands 3A which both increases the amount of moisture that can be evaporated (thus increasing cooling) and assisting in purging excess water from the system with the assistance of the wicks 40, as well as itself providing additional cooling. Additional wicks 46 may be provided in the passages 5 to assist in conducting water from the wick 40, aided by the flow of excess air or oxygen which permeates between the channels 2 and 3, through the membrane and over rounded tops of the lands 3A.

In a variation of the arrangement shown in Figures 17 and 18, the channels in the surface of the plate are of capillary size, for example V-shaped grooves of about 0.275mm depth and 0.35mm width, separated by 0.075mm lands. With such grooves, the capillary action they produce eliminates the need for separate wicks, and their wicking action may be enhanced by scribing the grooves in the material of the plates using a tool which leaves ragged edges at the lands. With such grooves, it is possible to dispense with separate air/oxygen and water grooves 2 and 3, and instead have the passages 4 and 5 communicate at regularly spaced locations (typically 180°) with the grooves so that air/oxygen passes through the grooves from the passages 4, picking up water on the way, and exits through the passages 5. Such grooves may be scribed, pressed or moulded as a continuous spiral, in the manner of a phonograph record, with the passages drilled or moulded adjacent the forward surfaces, with at least the passages 5 possibly being provided with wicks.

A further alternative core structure is shown in Figures 19 to 22. The core is formed by a stack of moulded plastic

disks 134, the end caps H and the stack of disks being secured by a through bolt passing through the passage 12. The disks also provide passages 4d, 5d, 6d, 7d which communicate with radial passages such as 4, 6 in the plates 1 through ports 4c, etc., as in previous embodiments. A seal forming compound is injected through a port 124a in one end plate into a manifold 125 and thence up channels 130 in the disks to a manifold and exit port 124b in the other end plate H. The sealant forms seals 112 between the perimeters of the electrode assemblies C, B, F, the flow field plates 1, and the disks 134. Further sealant passing up the passage 12 applies radial pressure to the disks (see Figure 20) to maintain them in tight contact with the plates 1.

It will be appreciated that in all the above embodiments in which fluid is caused to pass continuously through the grooves on one or both side of the plate, the passages of the second and third sets which provide inlets and outlets for the fluids must have a suitable capacity and be suitably externally connected so that appropriate pressure differentials may be maintained within the system.

CLAIMS:

1. A flow field plate comprising surface layers of electrically conductive material, and a core layer between the surface layers within the thickness of the plate; the plate defining multiple sets of fluid passages comprising first sets of passages, one set formed in the thickness of the core layer and extending transversely to the passages of the first sets to provide points of intersection with the latter when viewed in plan, ports placing passages of the second set in communication with passages of one or other of the first sets at points of intersection of the passages, and a third set of passages extending perpendicularly through the layers, without intersecting the first sets of passages, and each communicating with a passage or passages of the second set to provide fluid paths into, out of, or though the first sets of passages via the second set of passages.

2. A flow field plate according to claim 1, wherein the surface and core layers are integral, and the second set of passages is formed by drillings in the plane of the core layer.

3. A flow field plate according to claim 1, wherein the plate is of sandwich construction, with the surface and core layers formed separately, and the first and second sets of passages are formed separately in the layers, the second set of passage being formed by slots or recesses in the core layer.

4. A flow field plate according to claim 3, wherein the core layer comprises multiple layers, each formed to provide passages in said second set.

5. A flow field plate according to claim 3 or 4, wherein at least the core layer is formed from compressible conductive material, and the passages are pressed into the material.

6. A flow field plate according to claims 1-3, wherein each first set of passages is machined in the material of its respective surface layer.

7. A flow field according to any one of claims 1-6, wherein the passages of each first set are concentric and circular or single or multiple start helices.

8. A flow field plate according to any one of claims 1-7, wherein the passages of each first set have different cross-sections or spacings, according to their function, and/or their radial position.

9. A flow field plate according to any one of claims 1-8, wherein a set of first passages on one side of the plate is to carry hydrogen, and adjacent passages on the other side carry oxygen and water respectively.

10. A flow field assembly according to any one of claims 1-9, wherein the first passages are generally circular and concentric, the second passages are radial, and the third passages are parallel to the central axis of the first passages.

11. A flow field plate according to any one of claims 1-8, wherein at least one of the surface and core layers is formed of graphite.

12. A flow field plate according to any one of claims 1-11, wherein at least one of the surface and core layers is formed of a metal resistant to corrosion under the operating conditions prevailing in a fuel cell.

13. A flow field plate according to any one of claims 1-10, wherein the material at least one of the surface and core layers is rendered conductive by metallizing with a metal

resistant to corrosion under the operating conditions prevailing in a fuel cell.

14. A flow field plate according to claim 7, wherein the passages of the third set are located in plan radially inside or outside of an area occupied by the passages of the first sets.

15. A flow field plate according to claim 14, wherein the passages of the third set are formed by subdivision of a peripheral portion of the axial passage, with a central portion reserved for passage of an axial tension rod.

16. A flow field plate according to any one of the claims 1-15, wherein the plate defines multiple coplanar flow fields.

17. A flow field plate according to any one of claims 1-16, wherein at least the set of first passages formed in one surface layer communicates with at least two passages of the second set, one connected through a first third passage to a source of fluid, and the other connected to a further third passage receiving fluid.

18. A flow field plate according to claim 17, wherein a first passage of the second set is connected to alternate passages of the set of first passages and a second passage of said second set is connected to remaining passages of the set of first passages.

19. A flow field plate according to claim 18, including ports or permeation paths connecting said alternate and remaining passages of said first set, whereby surplus fluid can pass between said passages.

20. A flow field plate according to any one of claims 1-19, wherein at least some of the passages contain wicks.

21. A flow field plate according to any one of claims 1-19, wherein at least certain passages receiving water of reaction during operation of the plate contain wicks.

22. A flow field plate according to any of the preceding claims, wherein at least one passage of said second set contains a heat pipe to conduct thermal energy radially of the plate.

23. A flow field plate according to any one of claims 1-22, wherein at least the first passages of the set formed in one surface layer are grooves of sufficiently small dimensions to capillarize water.

24. A flow field plate according to claim 23, wherein lateral margins of the grooves are ragged to improve capillarization.

25. A cell stack comprising a stack of flow field plates according to any one of claims 1-24, interleaved by electrode assemblies comprising membranes sandwiched between porous electrode layers, the passages of the third set in each plate being in longitudinal communication parallel to a longitudinal axis of the stack, and means to compress the stack longitudinally.

26. A cell stack according to claim 25, wherein the passages of the first sets occupy annular areas on opposite sides of the flow field plates, and O-rings engaged in annular grooves radially inwardly and outwardly of these areas engage the membranes inwardly and outwardly of the electrode layers.

27. A cell stack according to claim 25, wherein the passages

of the first sets occupy areas on opposite sides of the flow plates, and moulded-in-situ seals of sealing material injected into voids formed in the stack inwardly and/or outwardly of these areas engage the membranes inwardly and/or outwardly of the electrode layers.

28. A cell stack according to claim 27, wherein the sealing material is injected through at least one passage of said third set.

29. A cell stack according to any one of claims 25-28, wherein sealing members associated with the third passages provide continuity and sealing of longitudinal passages through the stack formed by cooperation of the third passages.

30. A cell stack according to any one of claims 25-29, wherein the passages of the first set on opposite sides of each flow field plate are positioned to interdigitate when the stack is compressed.

Fig 1

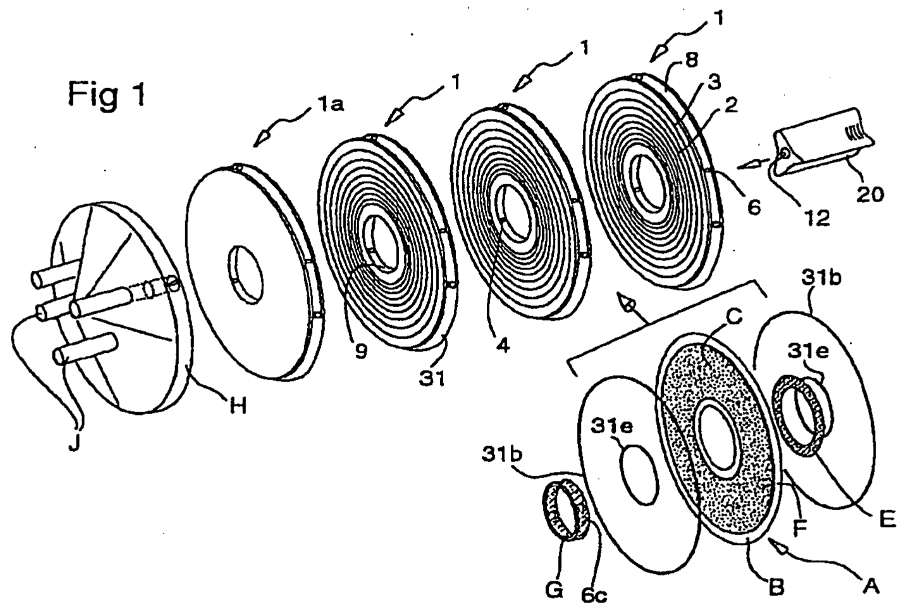


Fig 2

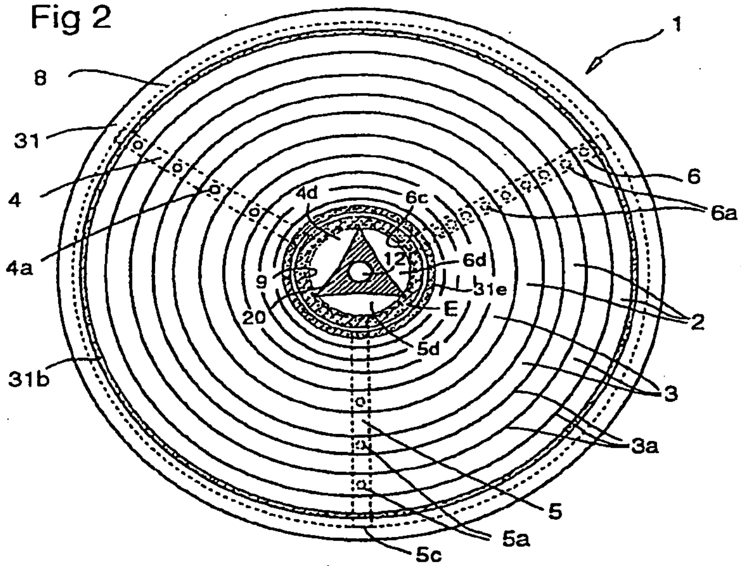


Fig 3

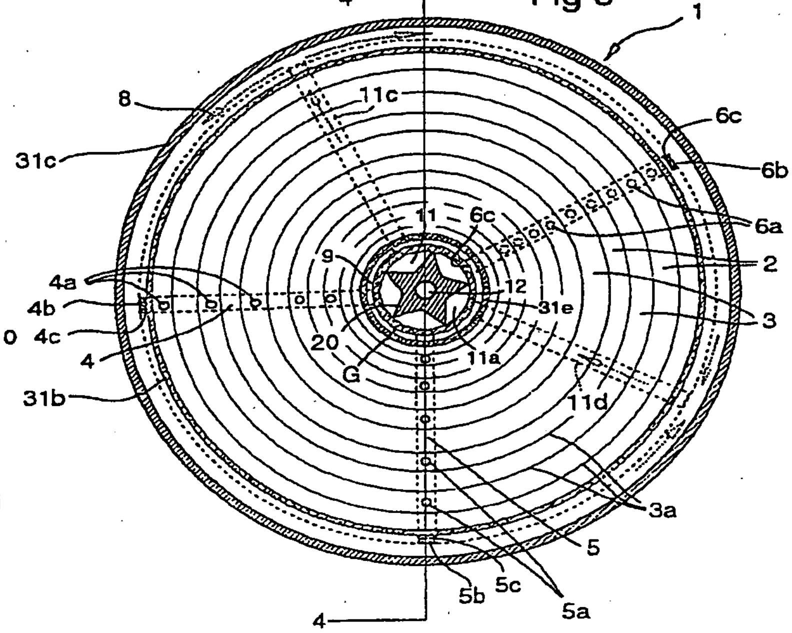


Fig 4

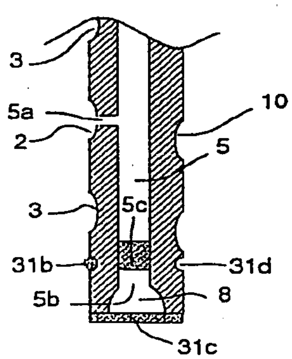


Fig 5

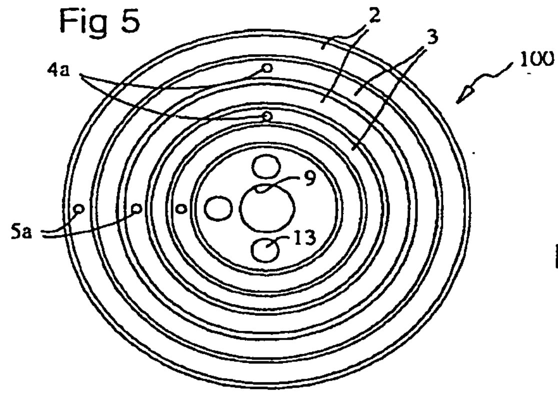


Fig 6

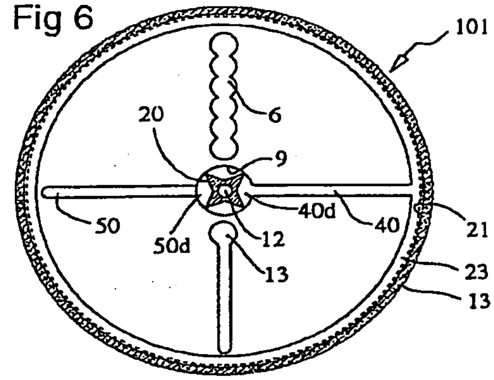


Fig 7

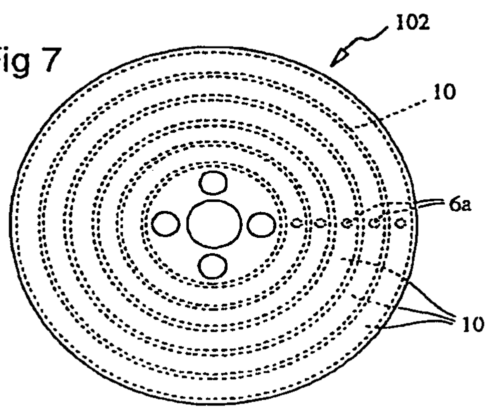


Fig 8

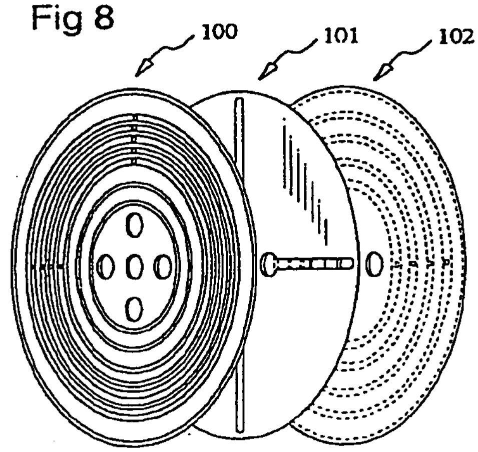
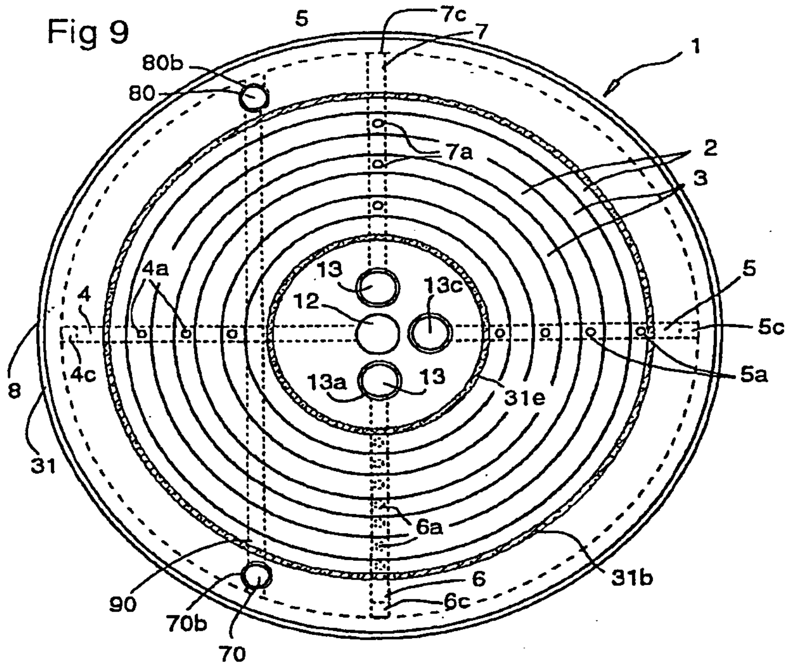


Fig 9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7
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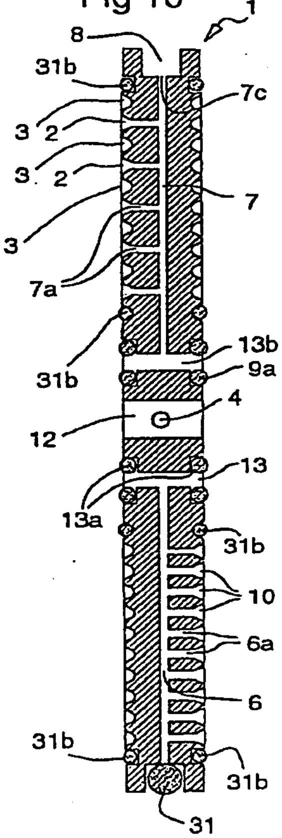
80b
80
7a
2
3
4a
4
13
13c
12
5
5c
4c
8
13a
13
31e
5a
31
6a
90
6
31b
70b
6c
70

Fig 10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31b
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7
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31b
10
6a
6
31b
31b
31

Fig 11

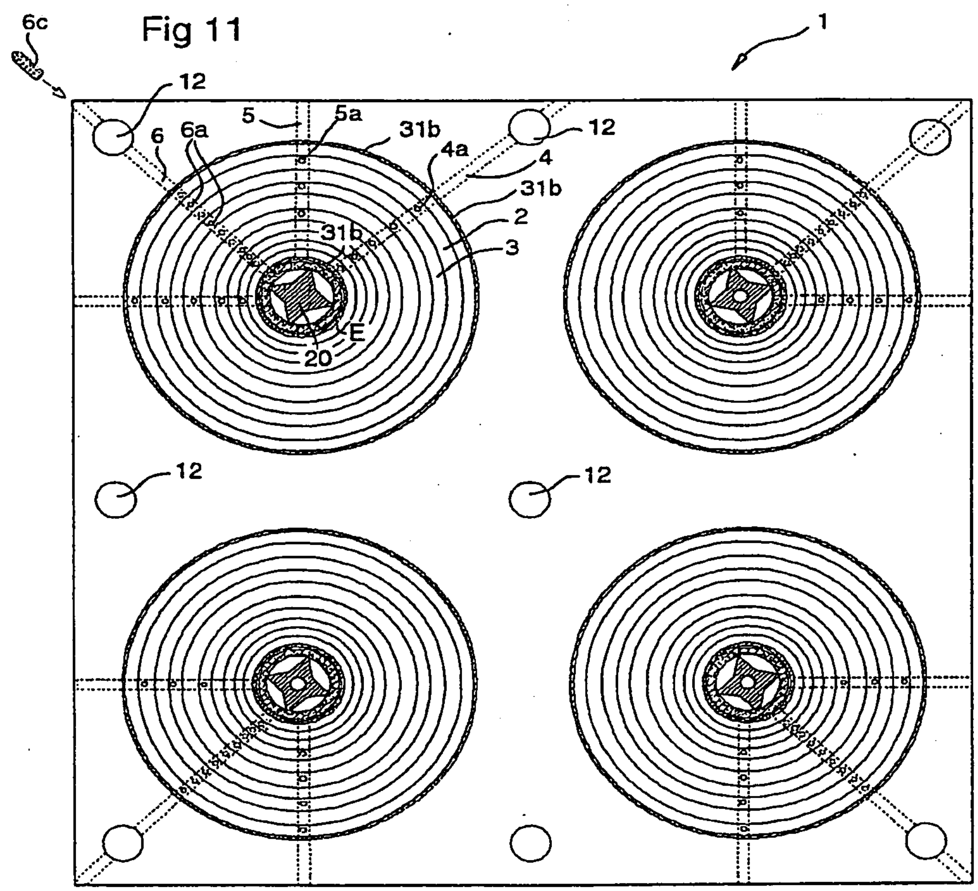


Fig 12

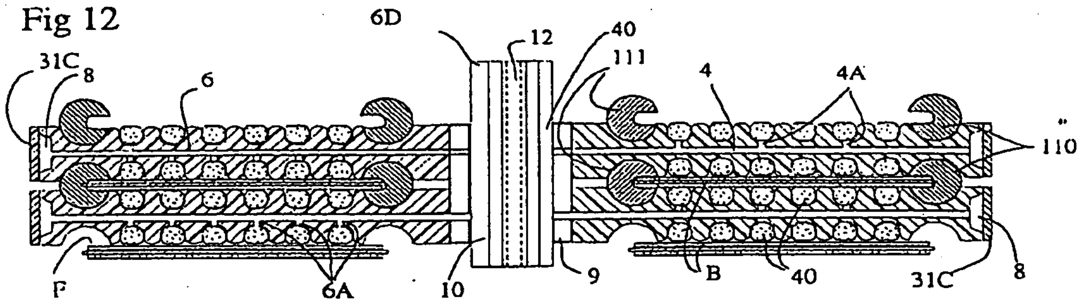


Fig 13

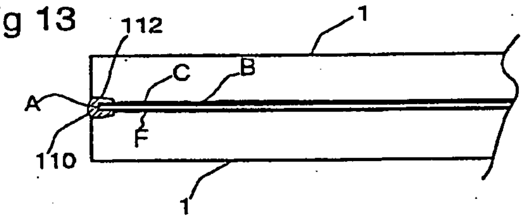


Fig 14

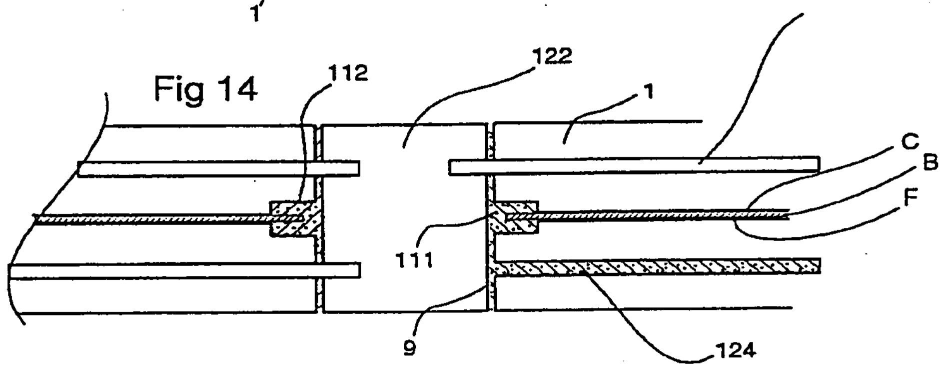


Fig 15

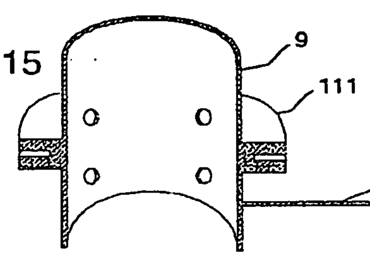


Fig 16

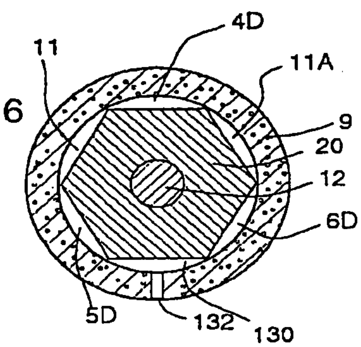


Fig 17

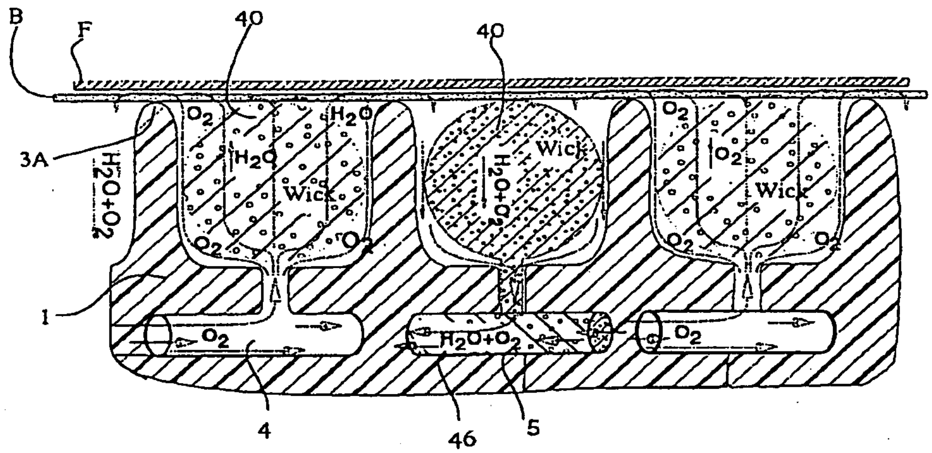


Fig 18

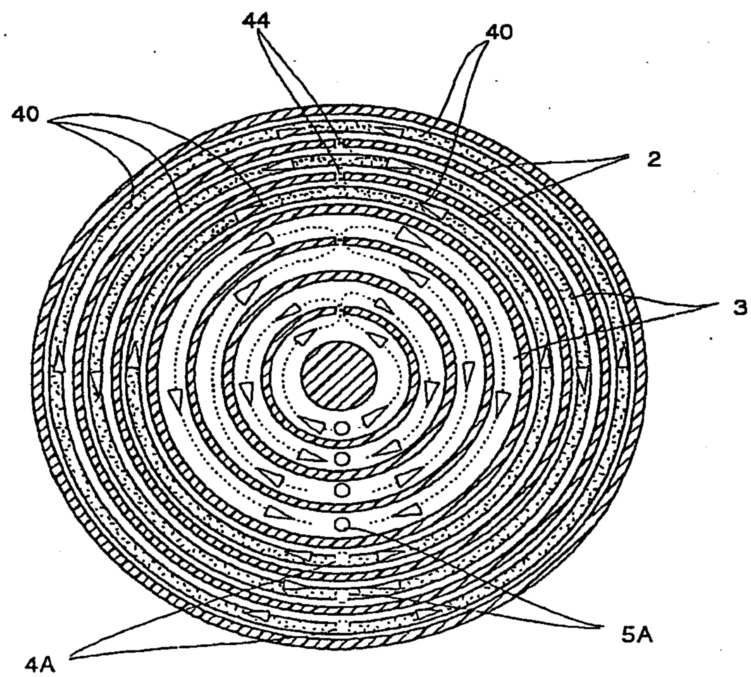


Fig 19

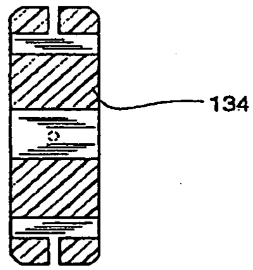


Fig 20

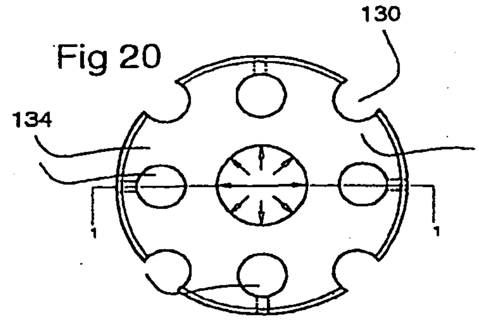


Fig 21

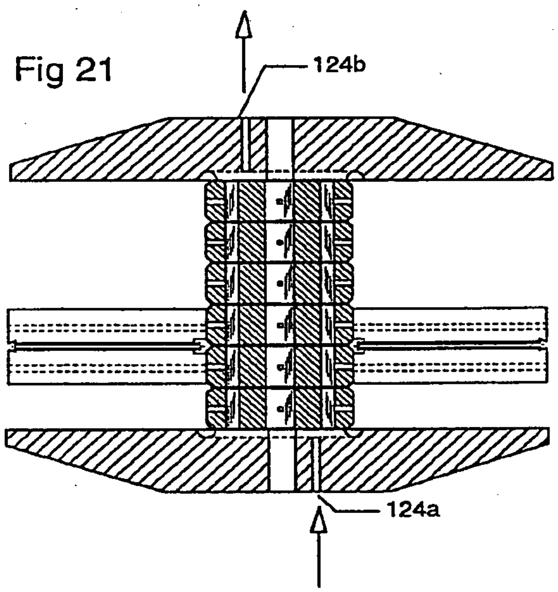
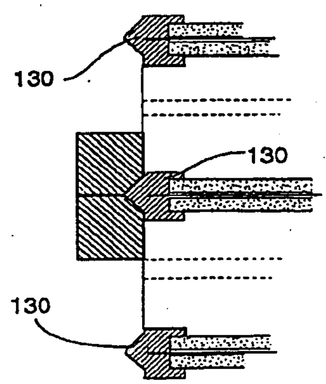


Fig 22



A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01M8/02 H01M8/24 C25B9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01M C25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 197 46 301 A (FUJI ELECTRIC CO LTD) 23 April 1998 (1998-04-23) column 6, line 29 -column 7, line 20; figure 1	1,6,7,9, 12,16, 20-23
A	DE 43 33 478 A (FUJI ELECTRIC CO LTD) 11 August 1994 (1994-08-11) column 5, line 1 -column 6, line 4; figures 2,3	1,6,7,9, 12,16, 20-23,25
A	US 4 490 445 A (HSU MICHAEL S) 25 December 1984 (1984-12-25) column 3, line 60 -column 4, line 42; figure 3	1,6,12, 16,25

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
25 October 1999	02/11/1999

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Andrews, M

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Interr nal Application No
PCT/CA 99/00583

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 08766 A (BALLARD POWER SYSTEMS ;JOHNSON MARK C (US); WILKINSON DAVID P (CA)) 6 March 1997 (1997-03-06) page 15, line 21 -page 16, line 2; claims 1,3,6,7; figures 3,8 page 18, line 8 -page 19, line 3	1,6,7,9, 12,16, 20-23

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